Sen2Cor 2.5 cloud masking and classification products

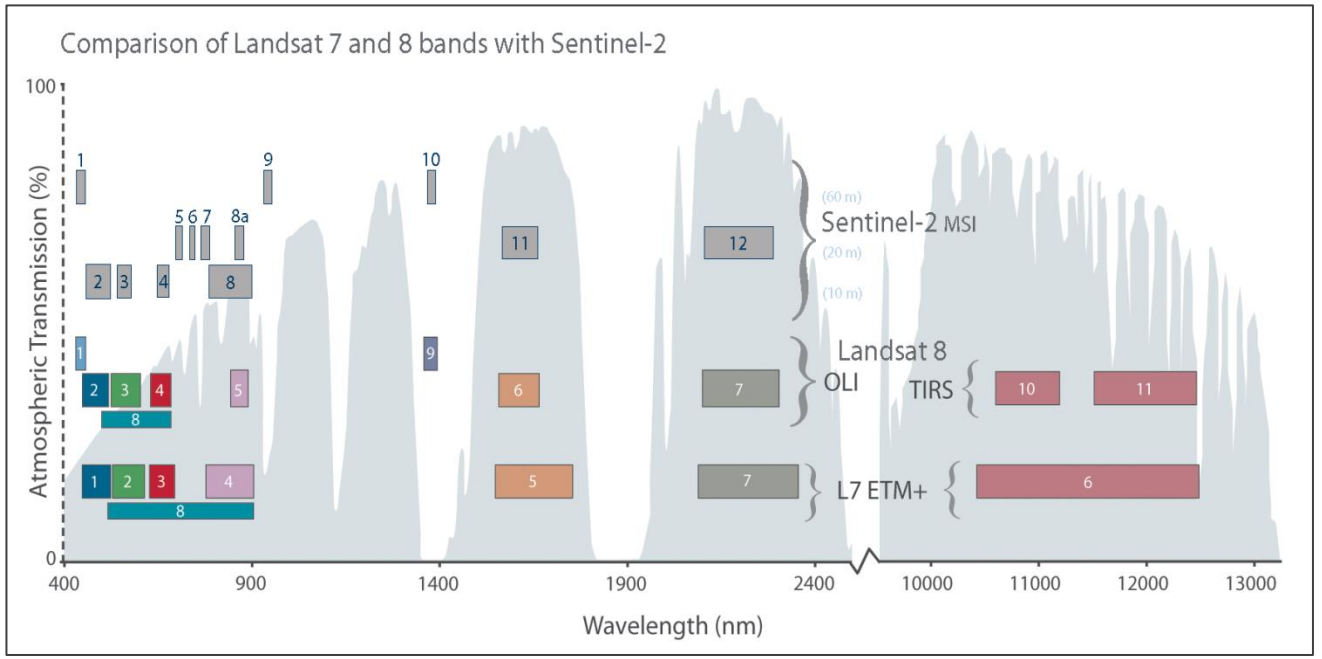
Magdalena Main-Knorn, Jerome Louis, Vincent Debaecker, Uwe Müller-Wilm,

Bringfried Pflug, Ferran Gascon

Sentinel-2 Mission

- optical mission for land and coastal region monitoring and emergency services
- Constellation of 2 satellites S2A and S2B
- Polar, sun-synchronous orbit at altitude: 786.13km with LTDN 10h30 AM
- Global coverage with swath of 290km and 5 days or less revisit period with both satellites
- 13 spectral bands with different spatial resolution (10 m, 20 m, 60 m).

Band	Center (nm)`	Spectral Width Δ (nm)	Spatial Re-solution (m)	Purpose in L2A processing context
B1	443	20	60	Atmospheric Correction
B2	490	65	10	Sensitive to Vegetation Aerosol Scattering
B3	560	35	10	Green peak, sensitive to total chlorophyll in vegetation
B4	665	30	10	Max Chlorophyll absorption
B8	842	115	10	Leaf Area Index (LAI)
B8a	865	20	20	Used for water vapour absorption reference
B9	945	20	60	Water Vapour absorption atmospheric correction
B10	1375	30	60	Detection of thin cirrus for atmospheric correction
B11	1610	90	20	Soils detection
B12	2190	180	20	AOT determination



Sen2Cor Processor and Products

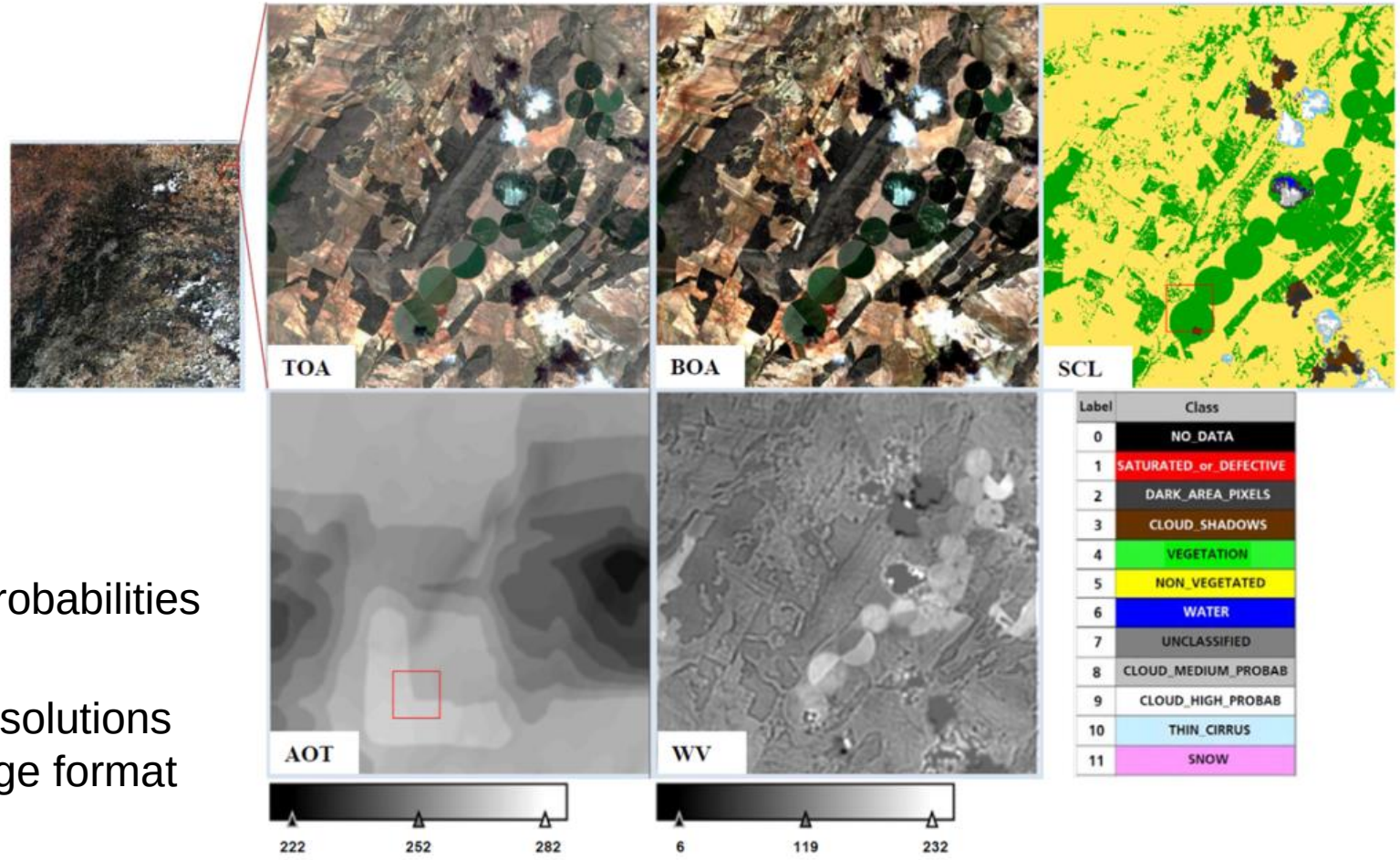
- Atmospheric correction processor, developed by Telespazio VEGA Deutschland GmbH on behalf of ESA

- Corrects single-date Sentinel-2 L1C Top-Of-Atmosphere (TOA) products from the effects of the atmosphere and delivers L2A Bottom-Of-Atmosphere (BOA) reflectance product

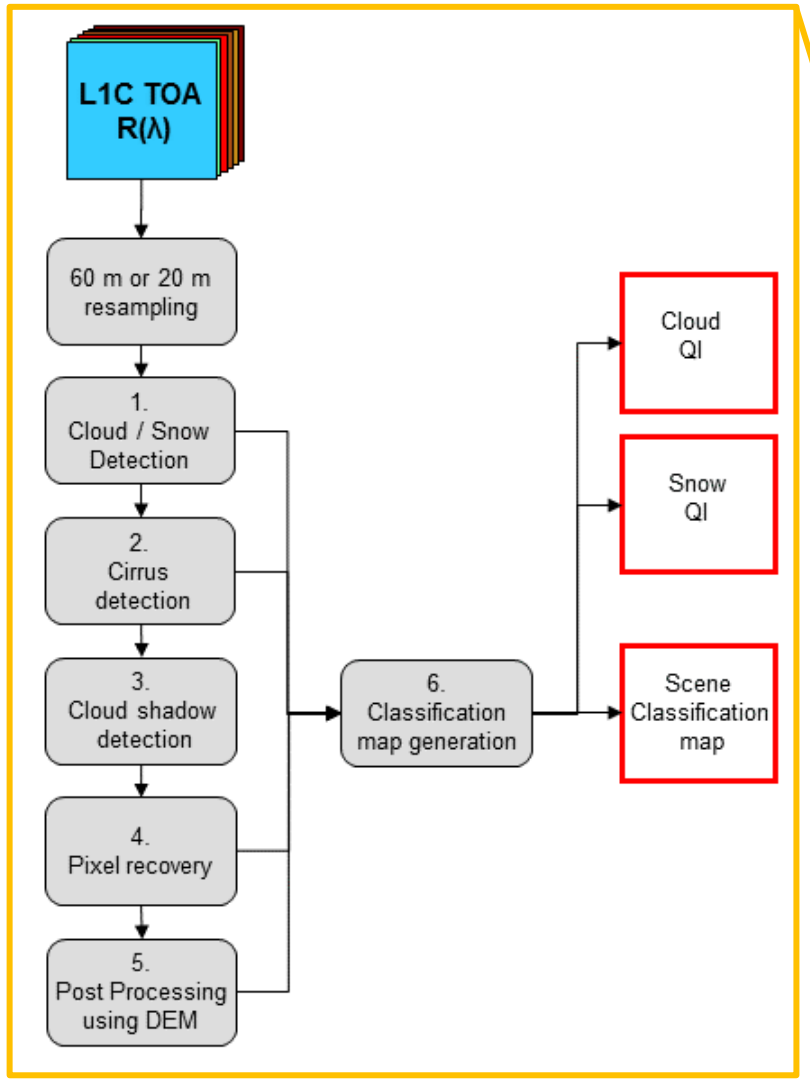
- Additional outputs:
  Aerosol Optical Thickness (AOT) map,
  Water Vapour (WV) map,
  Scene Classification (SCL) map,
  Quality Indicators for cloud and snow probabilities

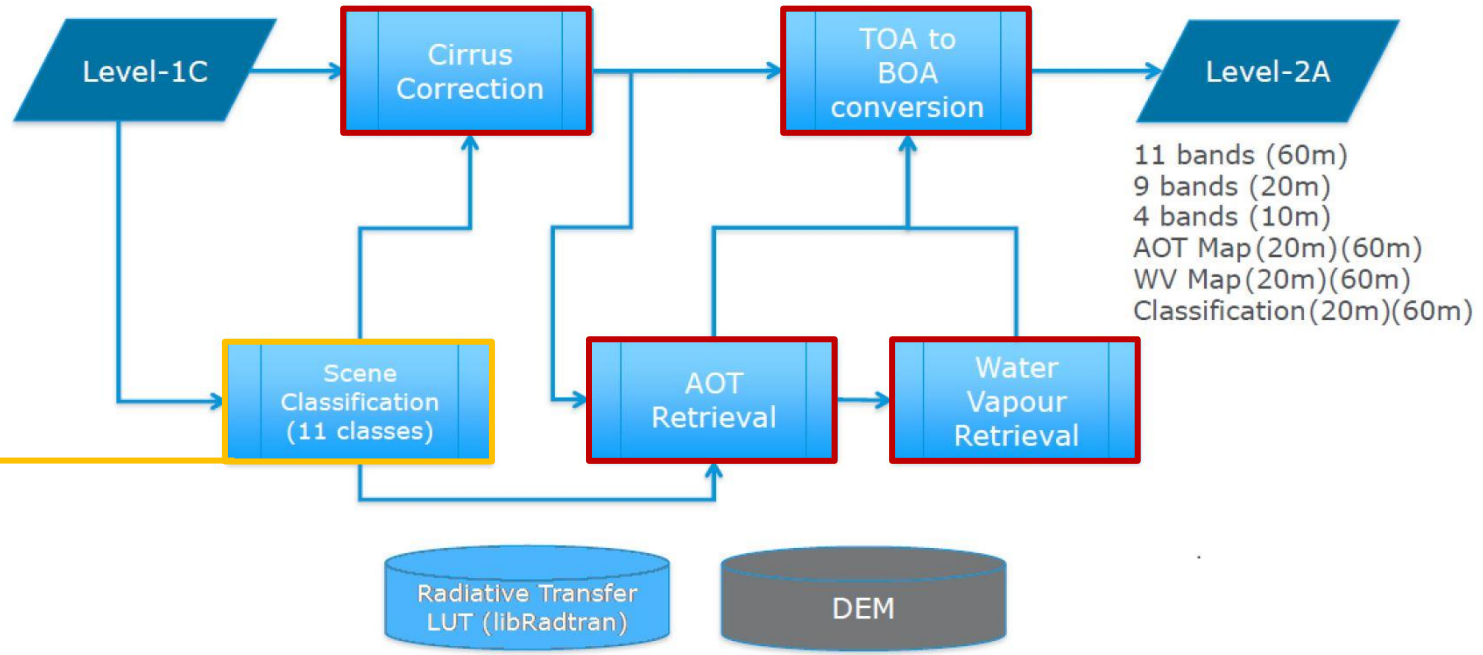
- Sen2Cor outputs provided for spatial resolutions 60m, 20m and 10m, in JPEG 2000 image format

Barrax (Spain) acquired on 19.05.2017, S2A_MSIL2A_20170519T105651_N0205_R094_20170529T104446



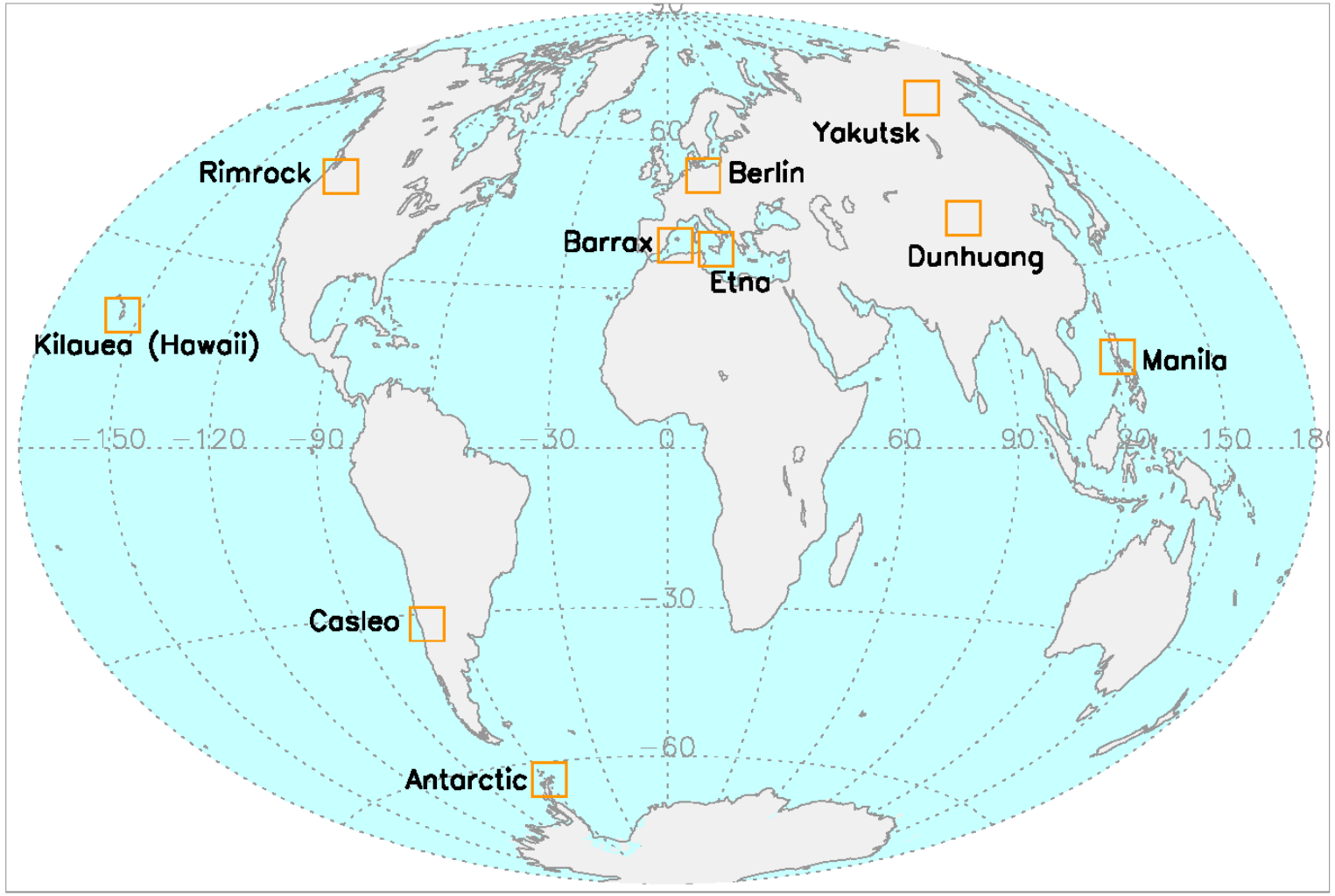
Sen2Cor Processor Framework - Scene Classification Module (SCL)





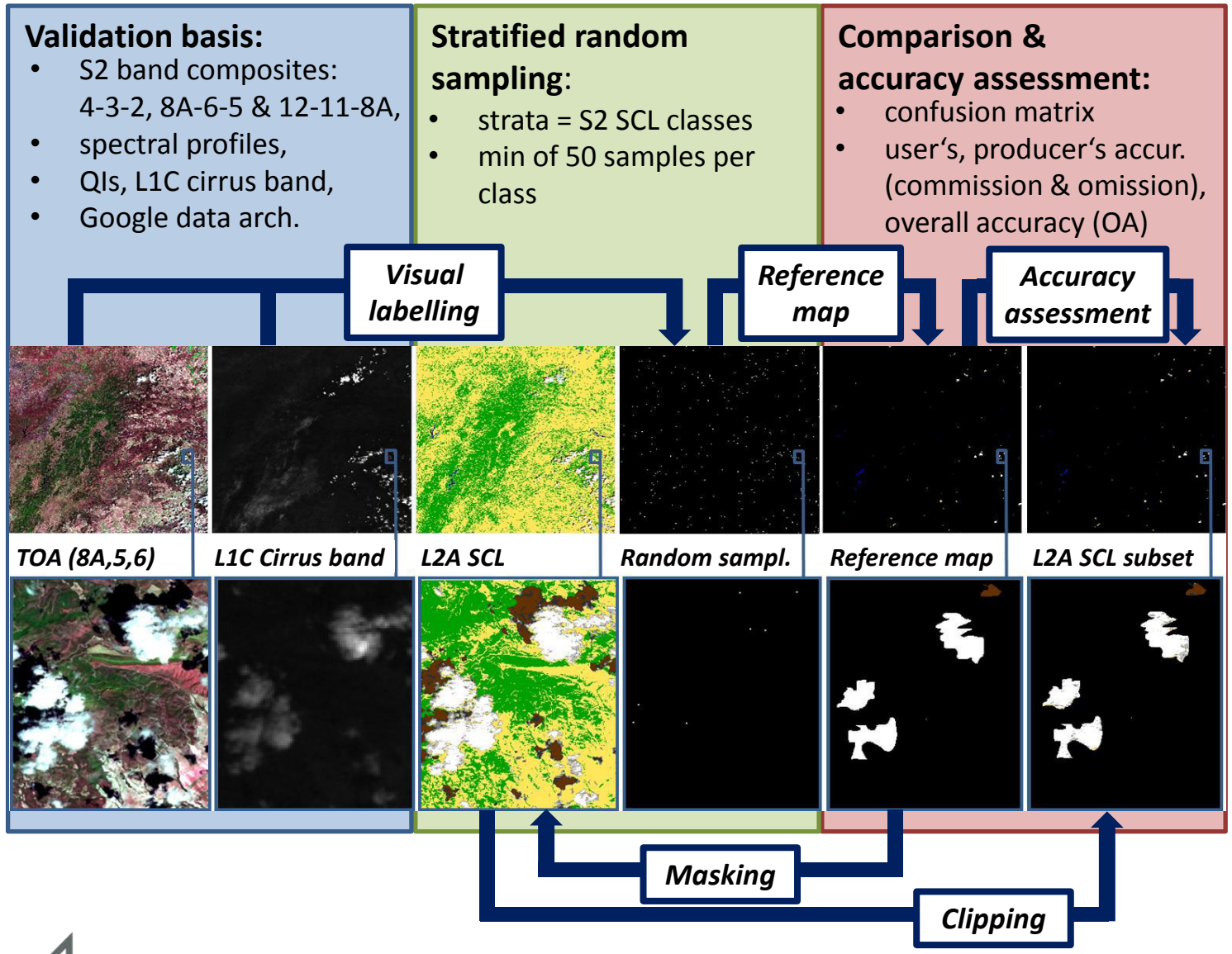
- Two main modules : Scene Classification (SCL), Atmospheric Correction (AC)
- DEM downloaded automatically by the processor (SRTM) or provided by the user in DTED format
- SCL is mainly based on a series of threshold tests on L1C spectral bands, band ratios and indices
- ESA CCI auxiliary data support for water and snow detection

Validation data set



- 10 validation sites
  - 7 core sites
  - 2 active volcanos sites
  - 1 polar site
- dataset covers different
  - atmospheric conditions
  - latitudes (various solar angles)
  - continents
  - topography and land cover type
- dataset covers not all seasons

Validation Procedure



- Statistical metrics:
  - Overall accuracy (OA)
    Percentage of correctly classified pixels.
  - Omission error (OE) / Producer Accuracy (PA)
    The share of reference pixels in that class that have been "omitted" in the classification image.
    OE [%] = 100 - Producer Accuracy
  - Commission error (CE) / User Accuracy (UA)
    Percentage of class pixels in the classification image which are falsely classified.
    CE [%] = 100 - User Accuracy
- Statistics are calculated for:
  - All classes (original SCL product)
  - Clear pixels (over land and water) separation
  - Clouds (medium- and high probability clouds, cirrus) separation

Validation of SCL Products

Site	Tile	Date	OA	OA clear pixels	OA clouds	Pixel validated
Antarctic	21EVK	2016/02/04	94,7	96,8	98,8	527803
Barrax (Spain)	30SWH	2017/05/09	64,6	96,9	98,7	141546
	30SWH	2017/05/19	90,5	98,7	99,5	104799
Berlin (Germany)	33UUU	2018/05/04	93,4	96,5	cloudless	51964
Casleo (Argentina)	19HDE	2016/08/12	63,8	86,1	98,1	186238
Dunhuang (China)	46TFK	2018/01/22	57,3	66,2	cloudless	105454
Manila (Phillipines)	51PTS	2018/03/19	82,1	90,0	91,6	106263
Rimrock (USA)	11TMM	2018/05/12	90,2	98,2	99,2	103394
Yakutsk (Russia)	52VEP	2016/03/08	69,9	93,8	92,9	177983
Etna Volcano (Italy)	33SVB	2017/03/09	95,8	97,9	99,4	132340
Kilauea Volcano (USA - Hawaii)	05QKB	2018/04/23	60,4	75,4	74,2	118357
		Average	**78,4**	**90,6**	**94,7**	159649
		St.dev	**14,6**	**10,2**	**7,8**	

(+) Good performance for majority of SCL products, very good performance for clear pixels and clouds detection

(–) Misclassification on bright surfaces, particularly on arid and semi-arid sites

(–) Confusion between 3 cloud classes – work ongoing on consolidation strategy

Validation of SCL Products

Class	Commission error	Omission error
dark_area_pixels	87,0	72,9
clouds_shadows	36,8	59,5
vegetation	24,5	13,0
non_vegetated	14,9	30,4
water	19,8	10,7
unclassified	98,2	87,0
cloud_medium_probability	81,7	79,7
cloud_high_probability	21,3	15,0
thin_cirrus	85,8	53,5
snow	11,3	20,7
Simplified statistics		
Clear pixels (land-water)	19,5	18,0
Others	17,1	12,7
Clouds	20,2	10,0
Others	6,0	3,2

(+) Good performance for vegetation, non-vegetated, water, cloud high probability and snow

(–) High commission and omission for dark area pixels, cloud shadows, unclassified, medium cloud probability and cirrus classes

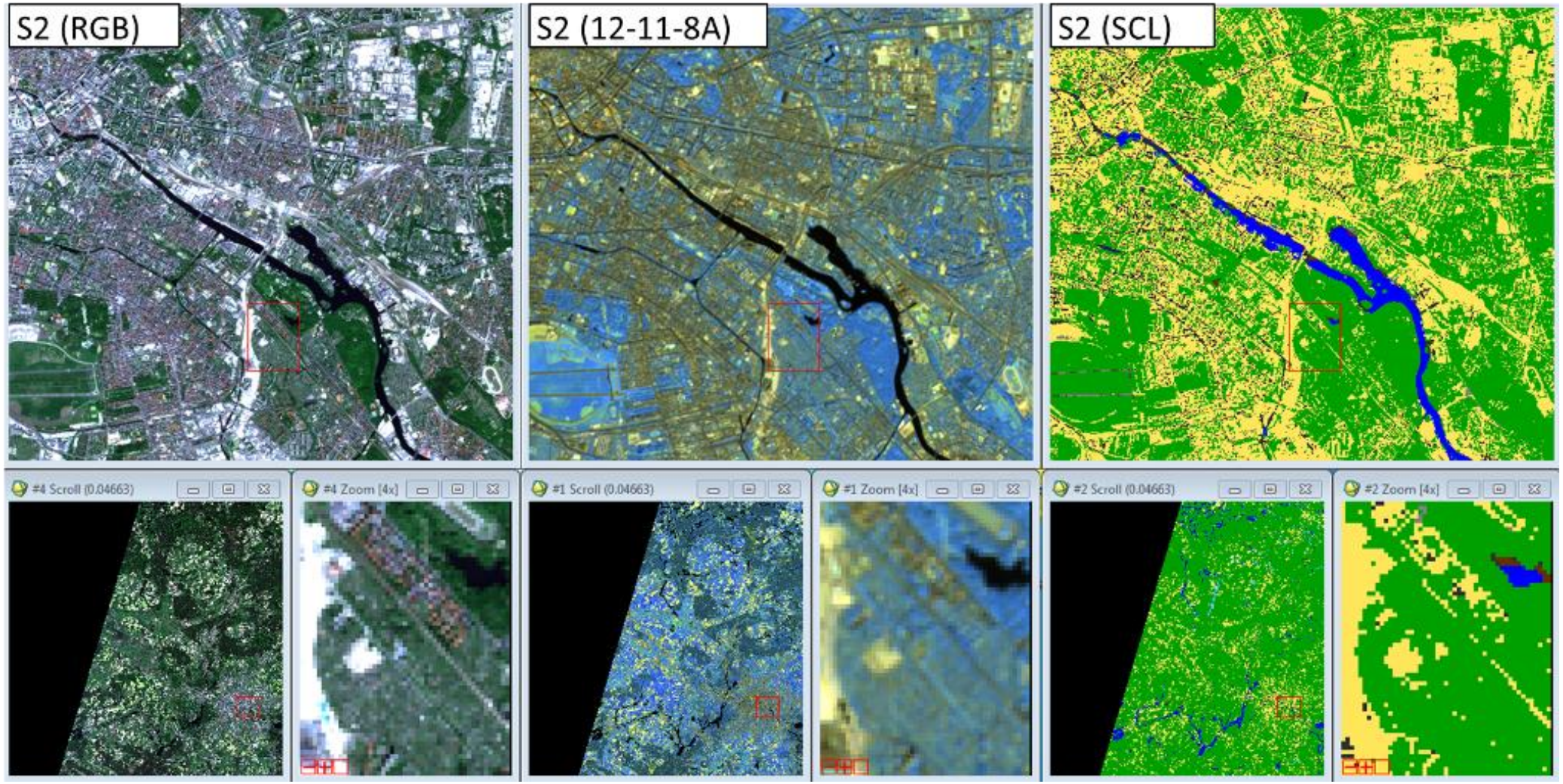
(–) Misclassification of bright surfaces, particularly on arid and semi-arid sites

(+) High performance for consolidated clear pixels and clouds detection

Validation example – Berlin

S2B_MSIL2A_20180504T101029_N0206_R022_T33UUU_20180504T122043.SAFE

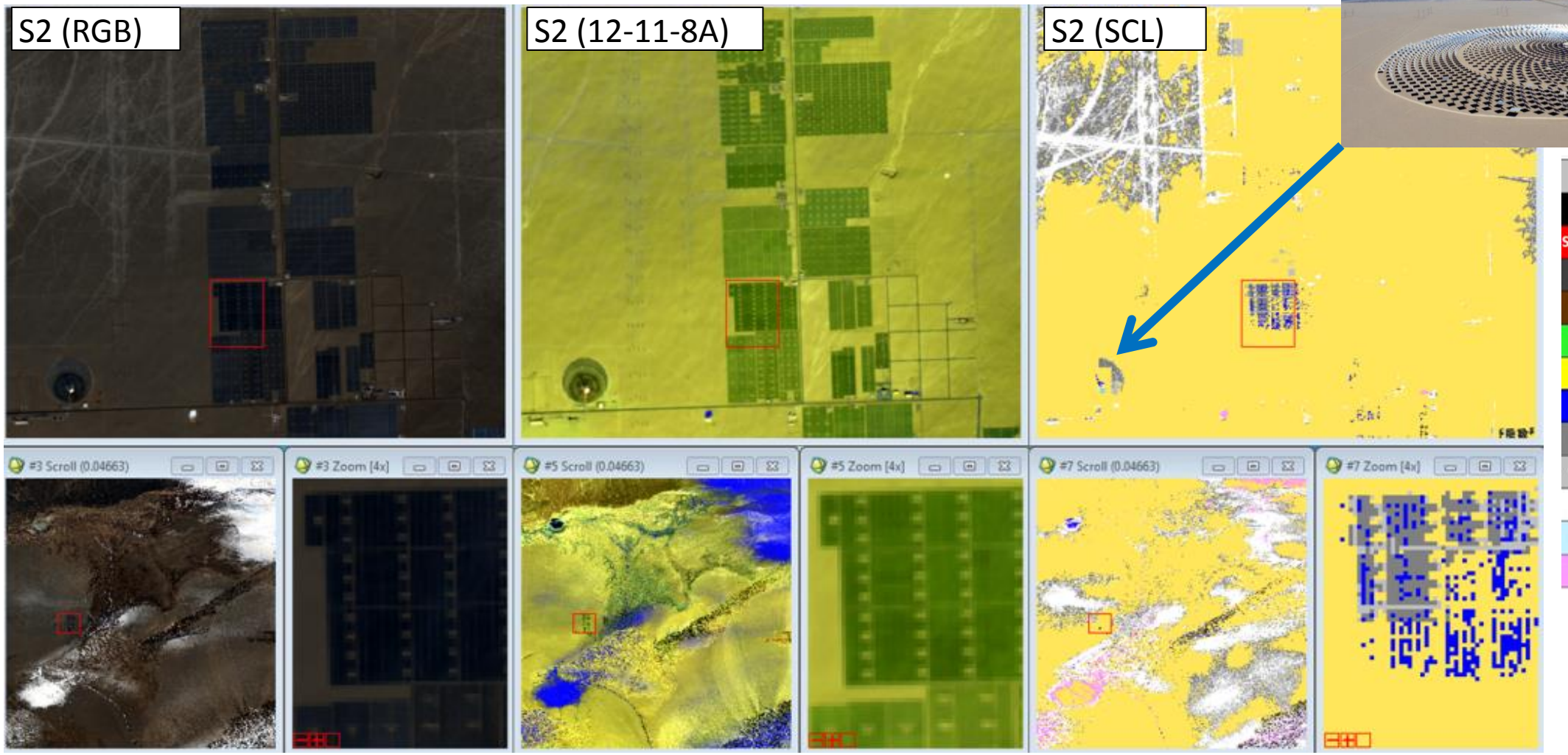
(+) Bright urban object in Berlin classified properly as land (non_vegetated)



Validation example – Dunhuang

S2B_MSIL2A_20180122T043059_N0206_R133_T46TFK_20180122T062244.SAFE

(-) solar panels, snow, sandy roads and dunes misclassified as clouds

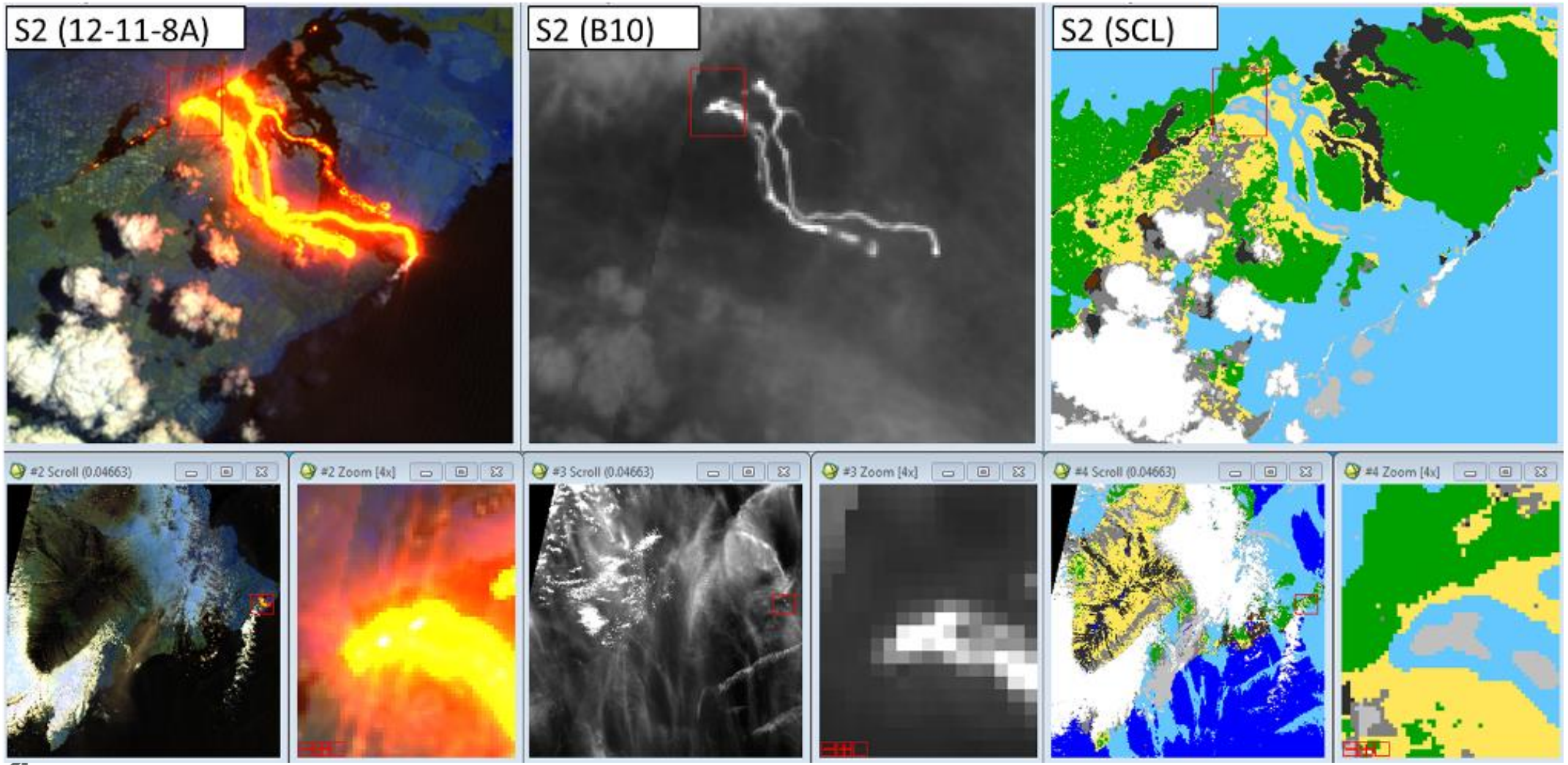


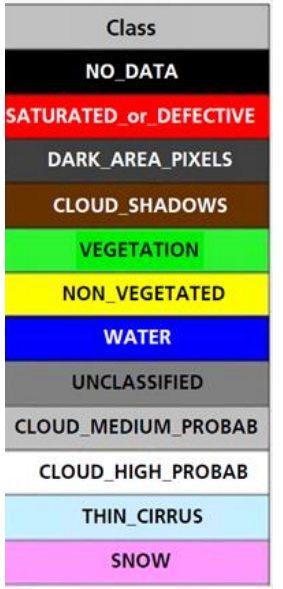
Class
NO_DATA
SATURATED_or_DEFECTIVE
DARK_AREA_PIXELS
CLOUD_SHADOWS
VEGETATION
NON_VEGETATED
WATER
UNCLASSIFIED
CLOUD_MEDIUM_PROBAB
CLOUD_HIGH_PROBAB
THIN_CIRRUS
SNOW

Validation example – Kilauea

S2B_MSIL2A_20180523T205939_N0206_R014_T05QKB_20180524T000522.SAFE

(-) fire classified as cirrus, burned area as dark area





Summary

- Averaged overall performance of Sen2Cor 2.5 for 11 products reaches 78,4 (±14,6)%
  - ➢ confusion between cloud classes
  - ➢ thin cirrus cloud definition and labeling is challenging
  - ➢ high misclassification rate for bright objects (urban, arid) – improvement needed, work ongoing
  - ➢ confusion between cloud shadows, topographic shadows and dark area pixels

- Good performance for clear pixels (over land and water) and clouds (3 cloud classes) detection:
  - ➢ Averaged OA for clear pixels separation: 90,6 (±10,2)%
  - ➢ Averaged OA for cloud separation: 94,7 (±7,8)%
  - ➢ Consolidated masks could provide high quality support for the users applications – work ongoing for forthcoming Sen2Cor processor evolutions

- Sen2Cor processor can be freely downloaded and used http://step.esa.int/main/third-party-plugins-2/sen2cor/
- L2A products over Europe are available: https://scihub.copernicus.eu/dhus/#/home
- Systematic global production is being implemented in the ground segment, will start in July 2018
- L2A Product Performance now reported in the L2A Data Quality Report:

  https://sentinels.copernicus.eu/documents/247904/685211/Sentinel-2-L2A-Data-Quality-Report

Thank you for your attention!

Magdalena Main-Knorn, Jerome Louis, Vincent Debaecker, Uwe Müller-Wilm, Bringfried Pflug, Ferran Gascon

magdalena.main-knorn@dlr.de; www.DLR.de/eoc